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CubeSat-Constellation-Based Global Early Warning Tsunami Forecasting

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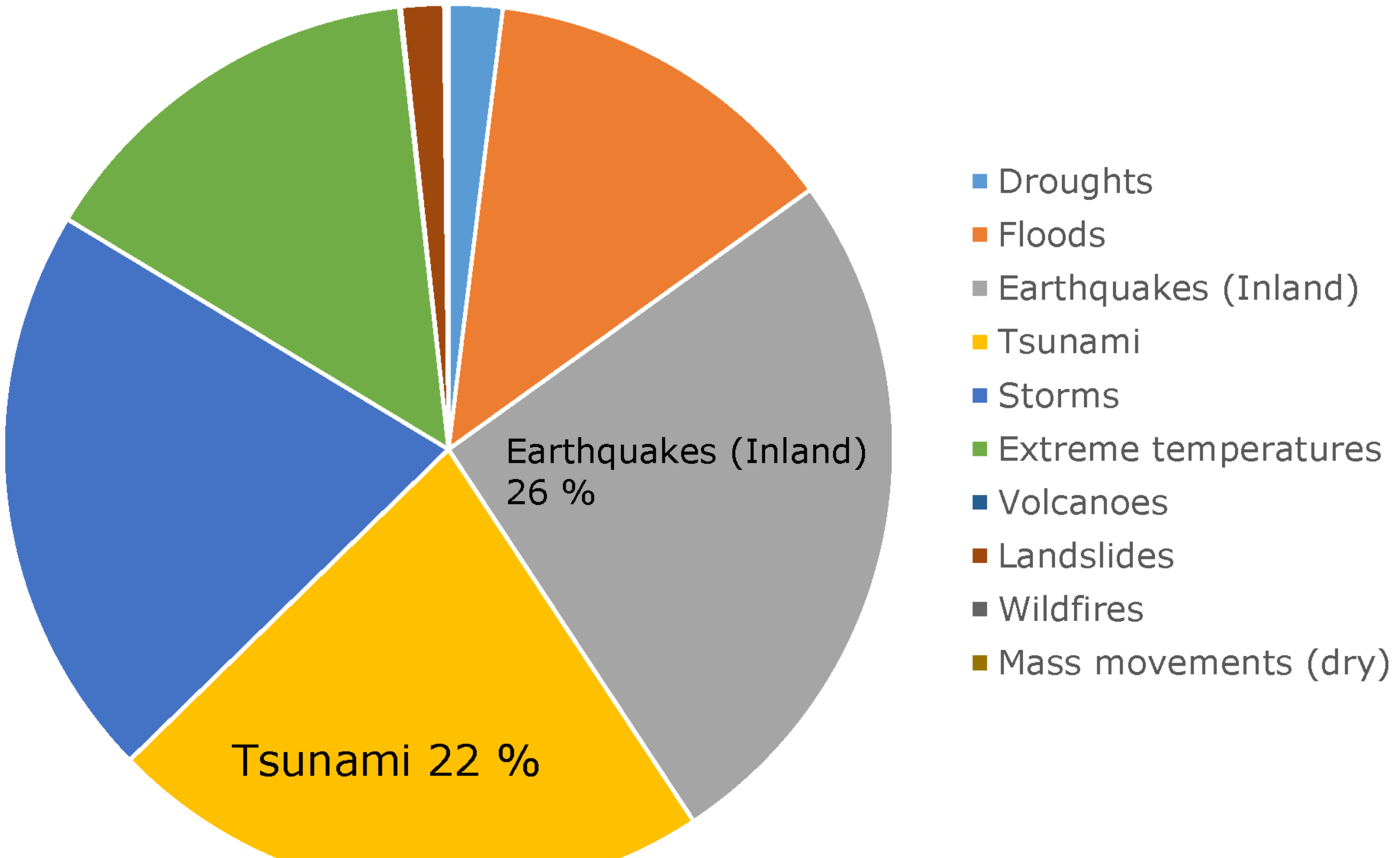
Natural Disaster 1996-2015



Total deaths: 1,141,588

Origin of Tsunami

(After NOAA)

How to issue the forecast?

~3 min

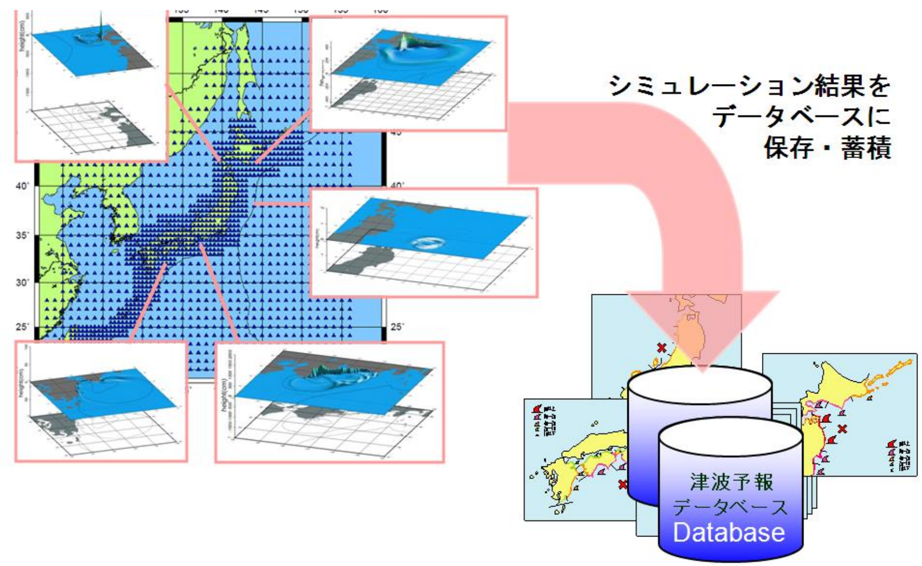
~30 s

Hypocenter and Magnitude

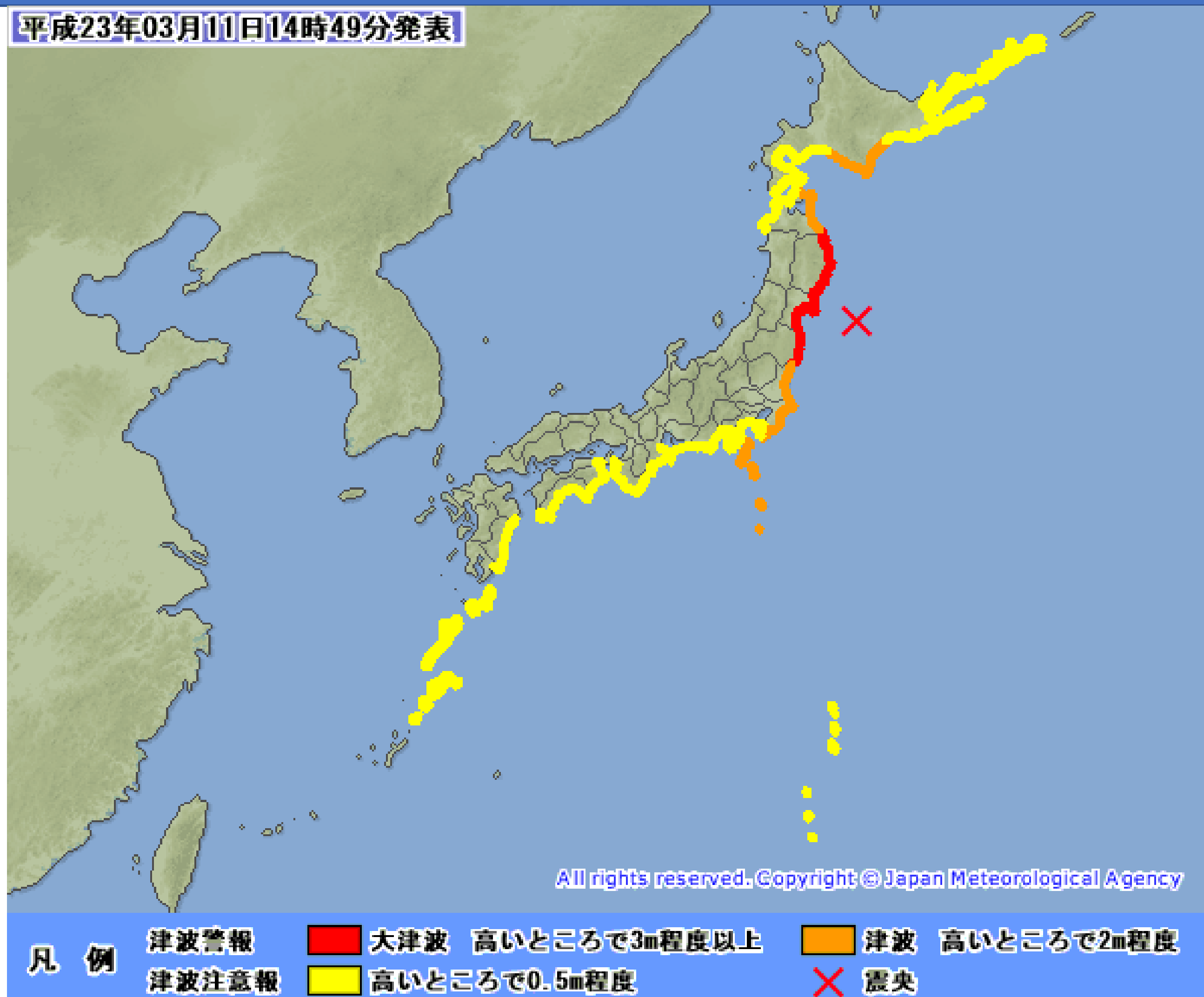
Plausible tsunami height is extracted from database based on various fault plane assumption.

Tsunami forecast database (JMA)

Various fault plane are assumed for the tsunami calculation.

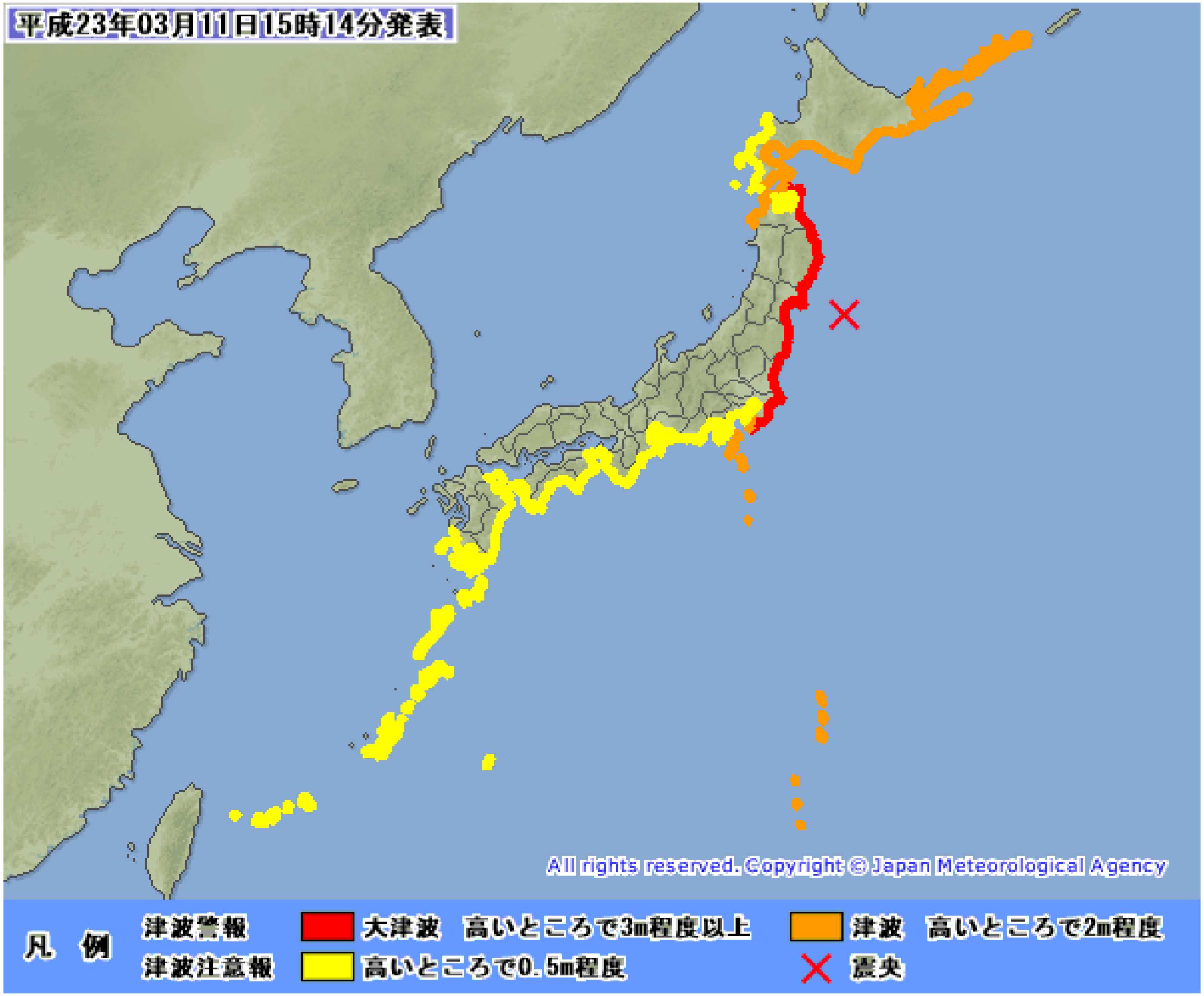


Example forecast:
3 min after 2011 Tohoku earthquake (EQ) Magnitude (M) 7.9 -> under estimated!

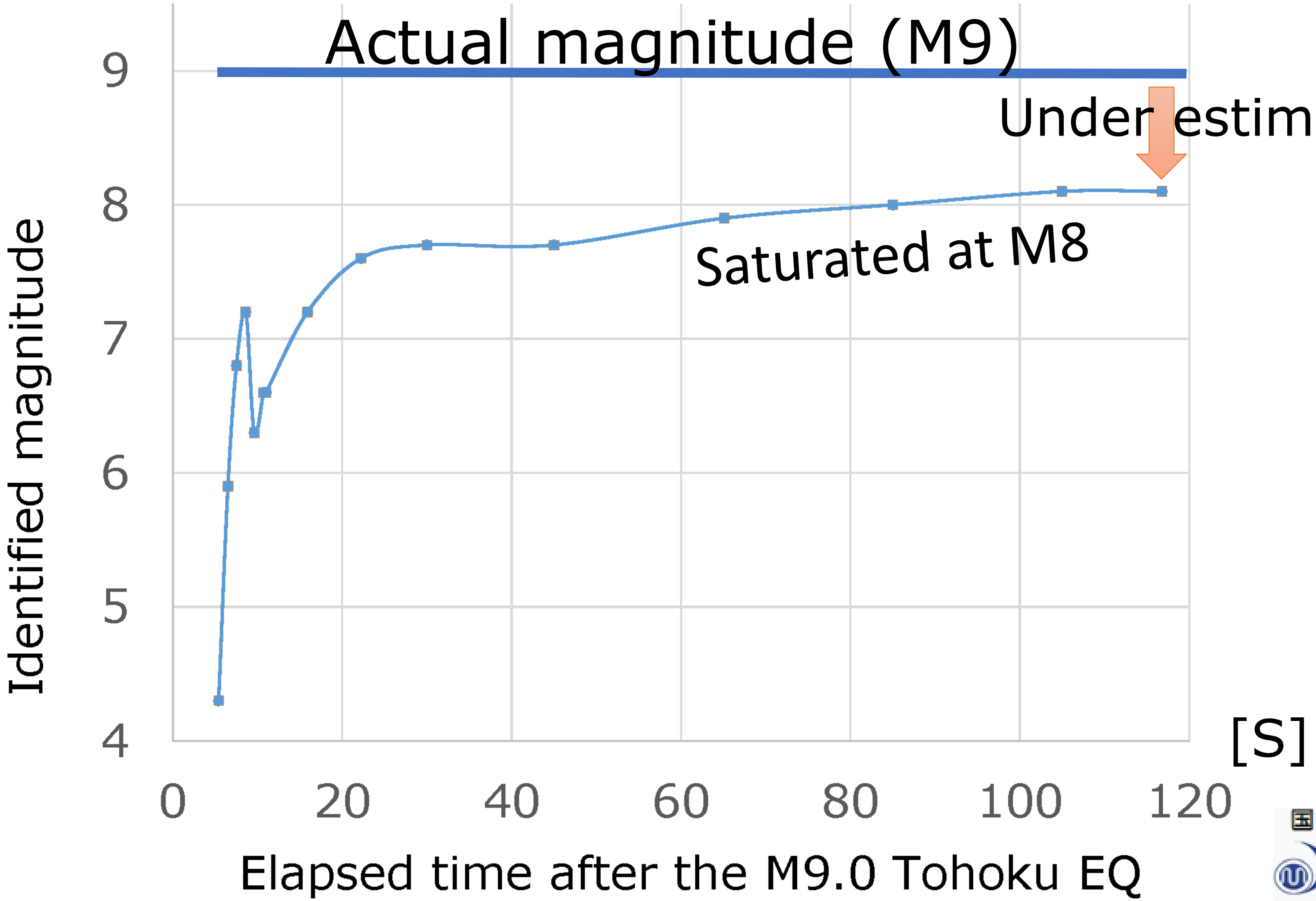


28 min after 2011 Tohoku EQ
Magnitude (M) 8.1 -> under estimated!

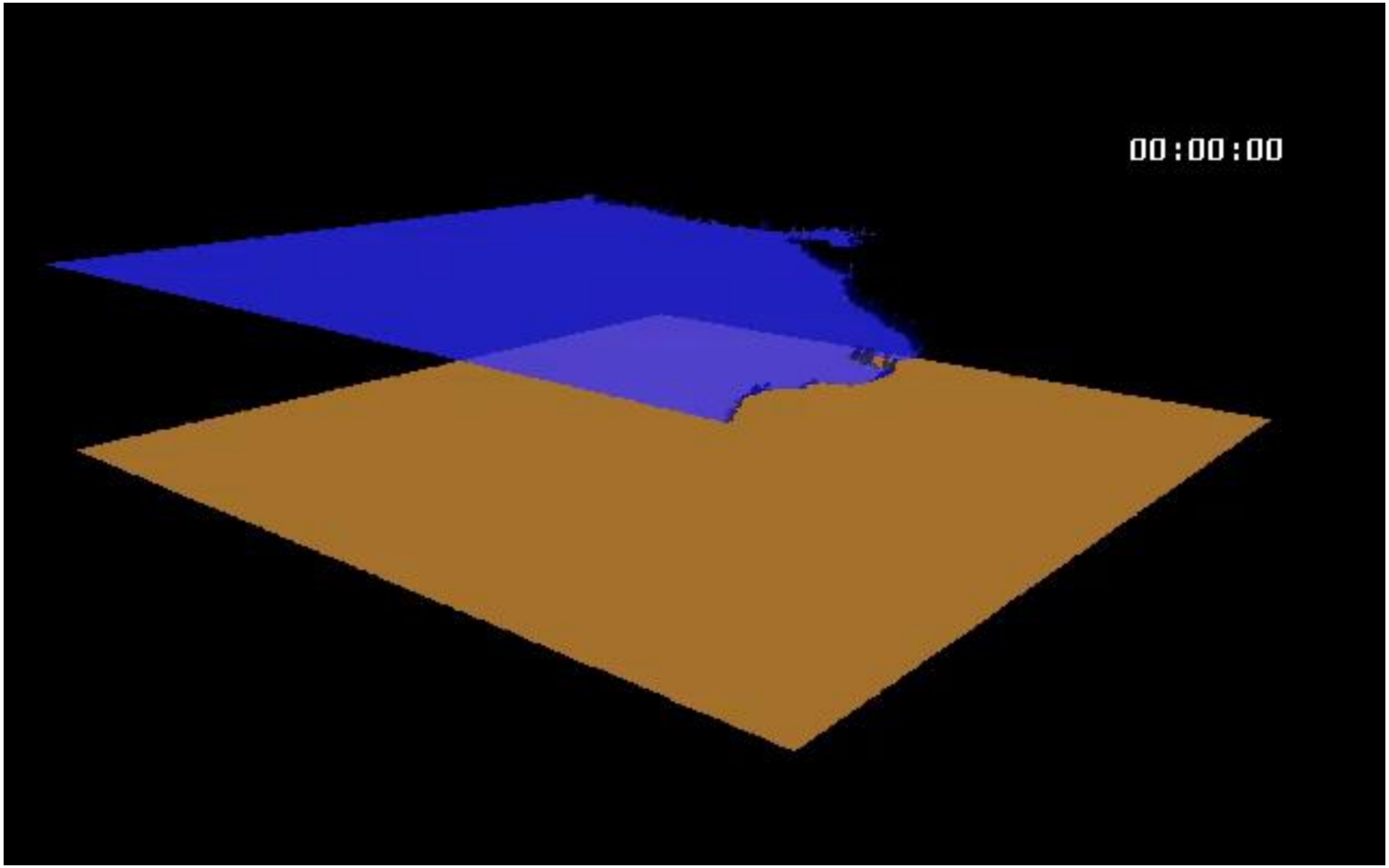
Neptune



Estimated magnitude after the Tohoku EQ



Initial tsunami source is required for accurate tsunami forecast

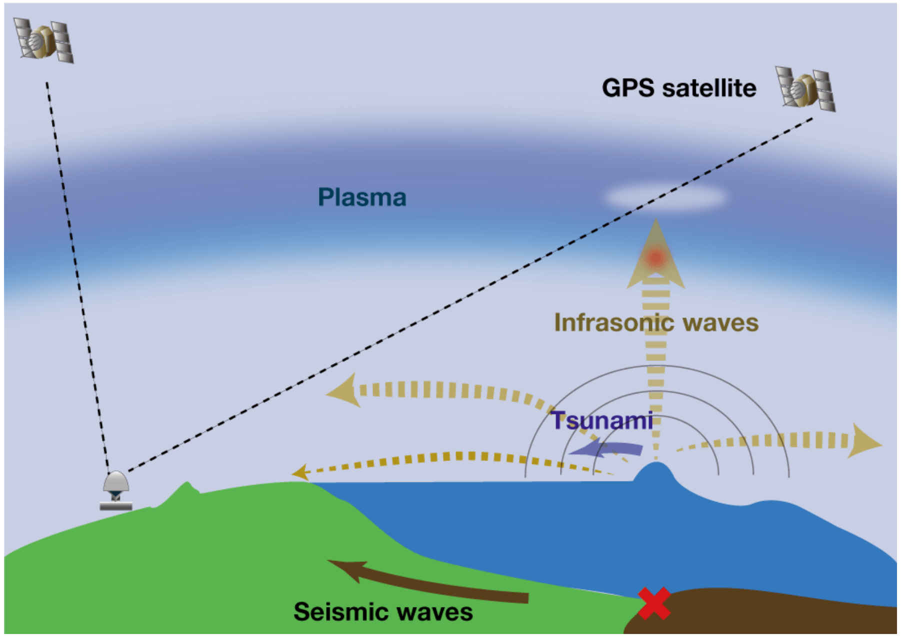


Why is tsunami forecast difficult?

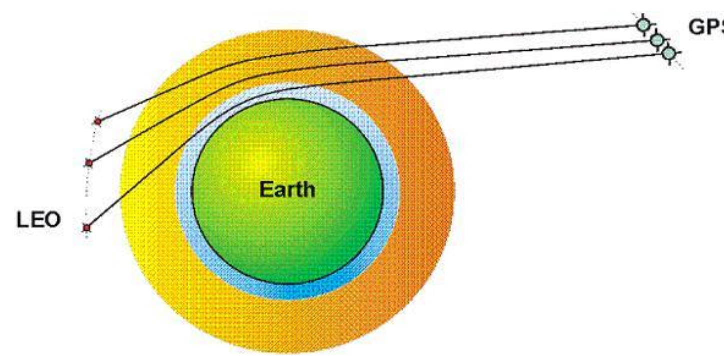
Neptune

- It is impossible to estimate magnitude of more than 8 immediately after the large EQ.
- Fault plate slip estimated by seismic wave is not always coincident with tsunami source.
- So far, no direct measurement of tsunami source.

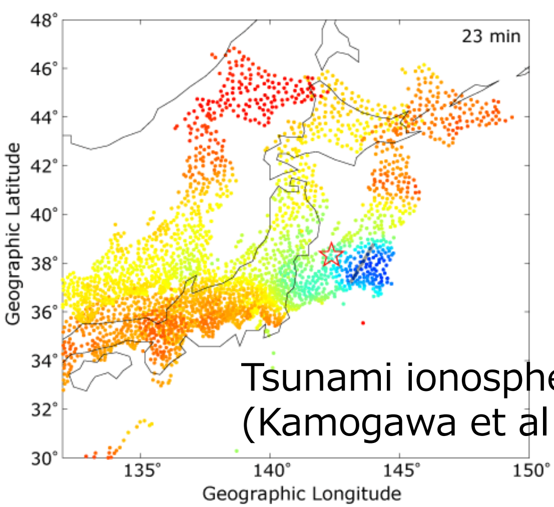
Tsunami ionospheric hole



Global navigation system satellite radio occultation (GNSS-RO) measurement can measure the tsunami ionospheric hole.



Many low-earth-orbit (LEO) satellite consternation can measure ionospheric electron density.

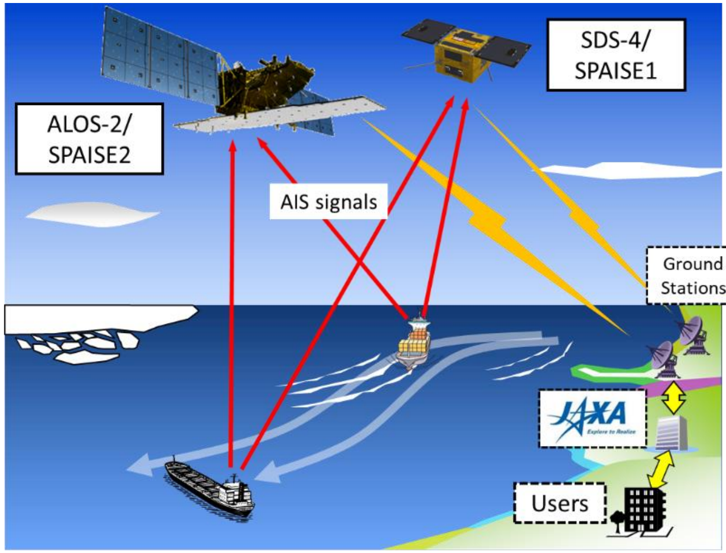


Tsunami ionospheric hole (Kamogawa et al., 2016)

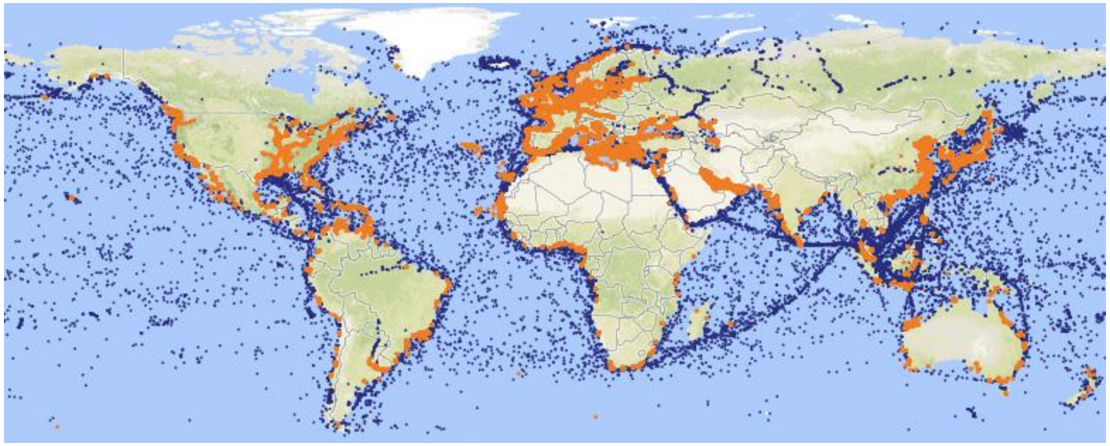
Tsunami source is estimated from the ionospheric electron density depression.

Method 1

Vessels crossing tsunami inform the tsunami velocity through VDES (VHF Data Exchange System)



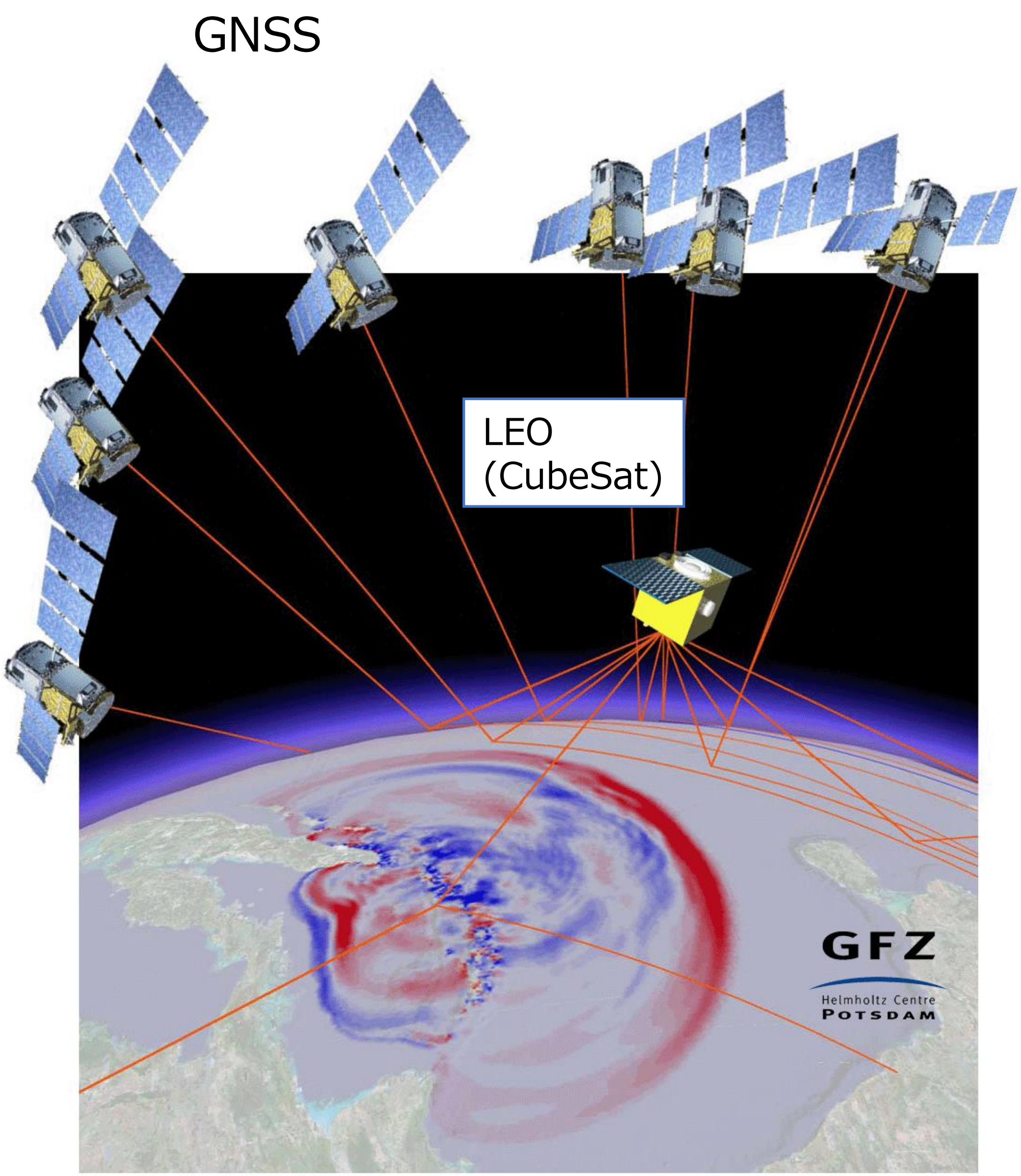
- ✓ VDES (former AIS) can obtain vessel information (location, velocity, direction etc) via satellite.
- ✓ When tsunami wave across the vessel, VDES includes tsunami velocity information.
- ✓ Various VDES data inversely estimate the tsunami source.



Vessel distribution identified by VDES (Vesseltracker.com)

Method 2

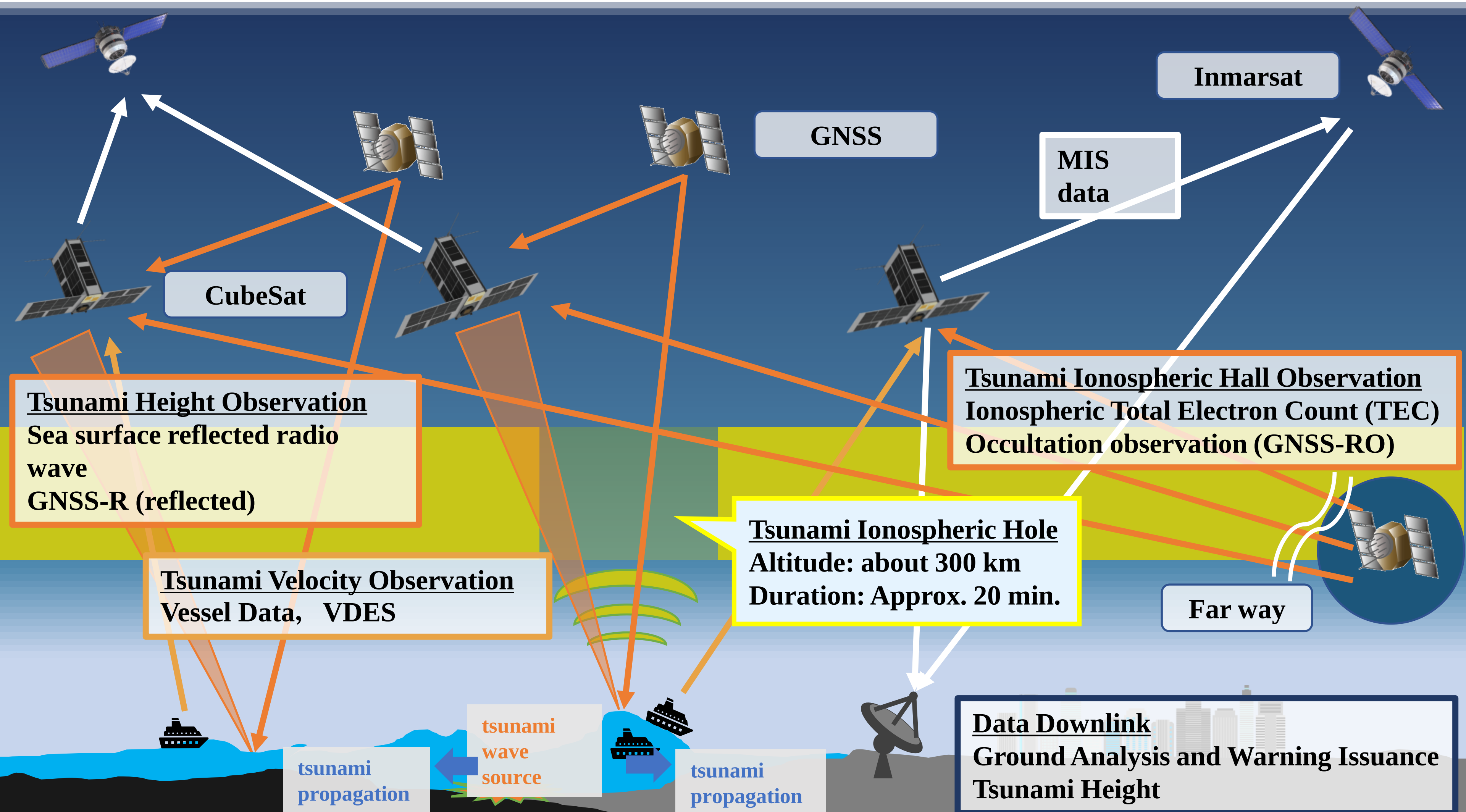
Propagating tsunami height measured by GNSS reflectrometry (GNSS-R).



GNSS-R can measure the sea height as well as tsunami height.
Multi-point tsunami height data provide the tsunami source through inversion analysis.

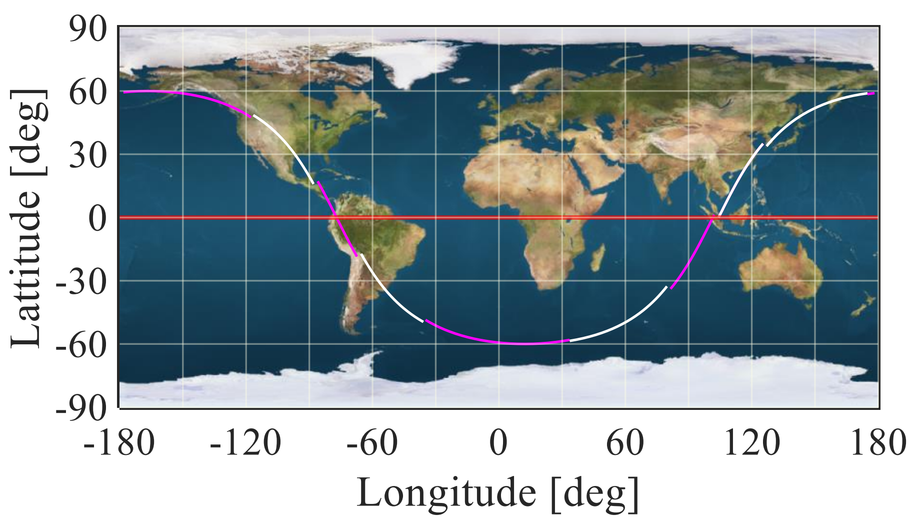
Method 3

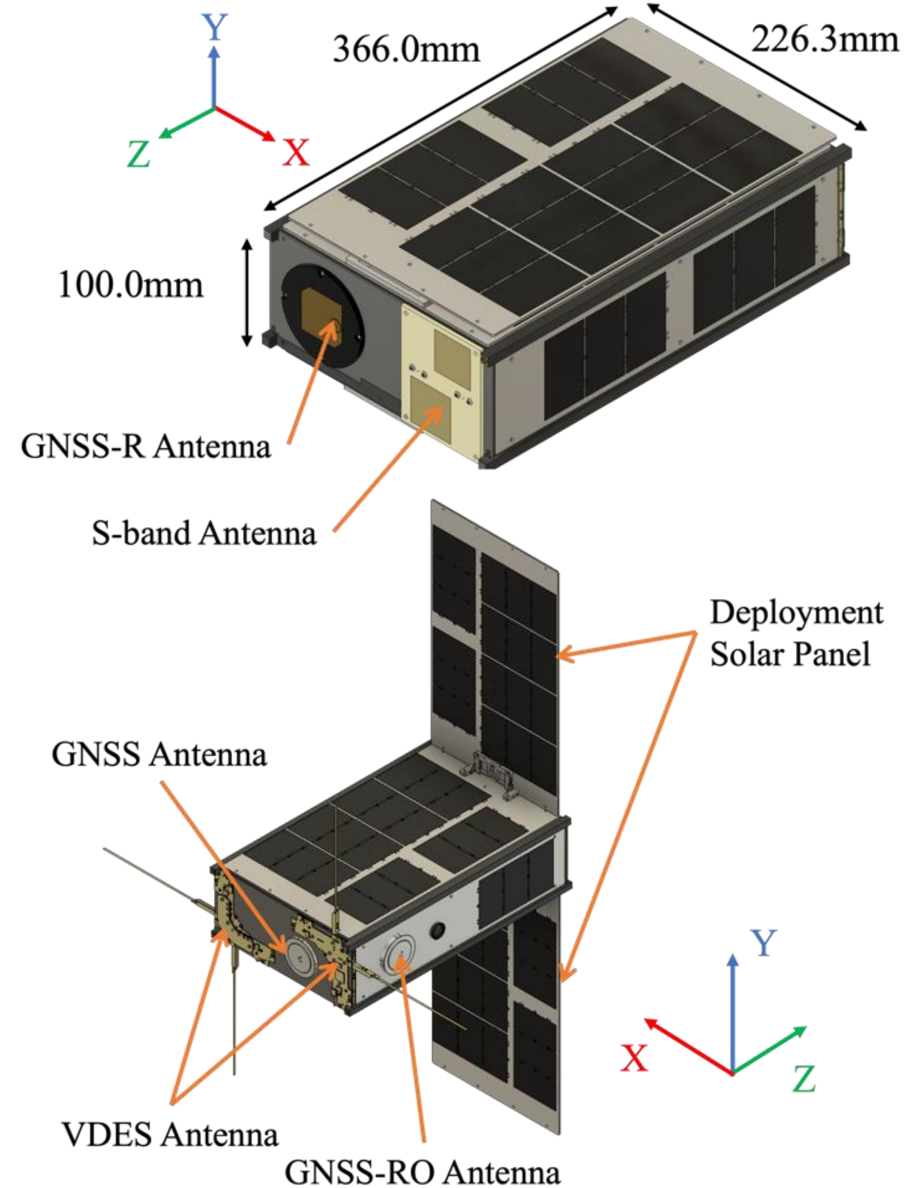
Summarize of operations



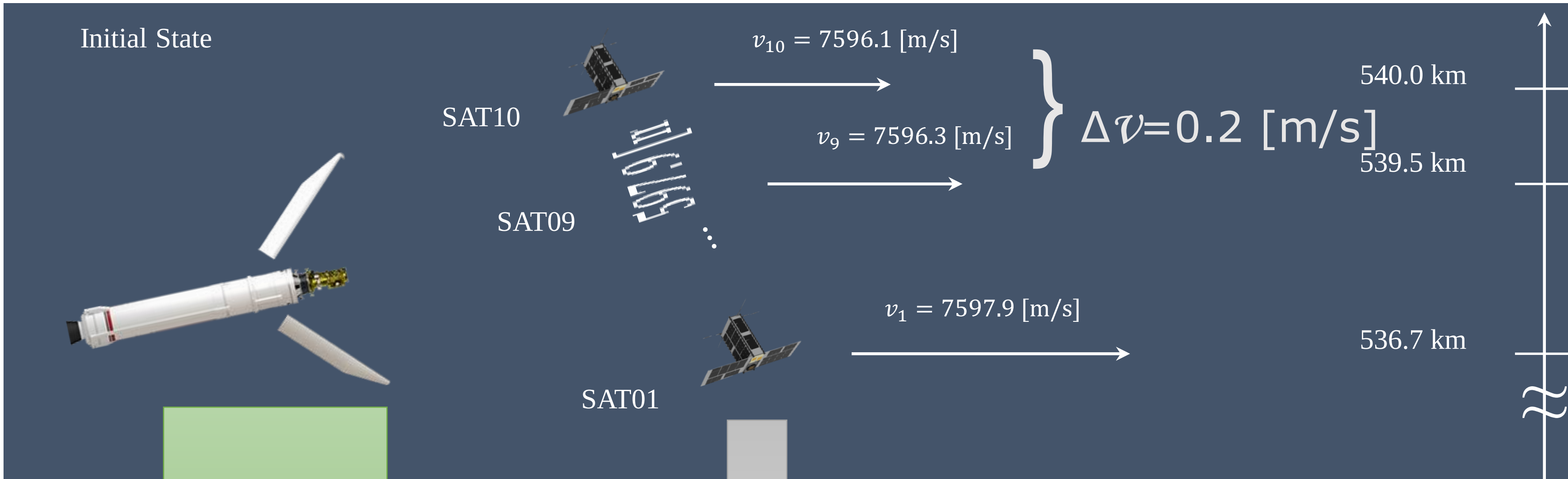
CubeSat

Orbit	Non-sun-synchronous orbit (Inclination: 60 degrees)
Altitude	500 ～ 700 km
Launch	Main satellite
Size	100 mm × 226.3 mm × 366 mm
Weight	7.828 kg
Communication	Uplink：S-band Downlink：S-band Realtime: Inmarsat
Mission life	2.5 years





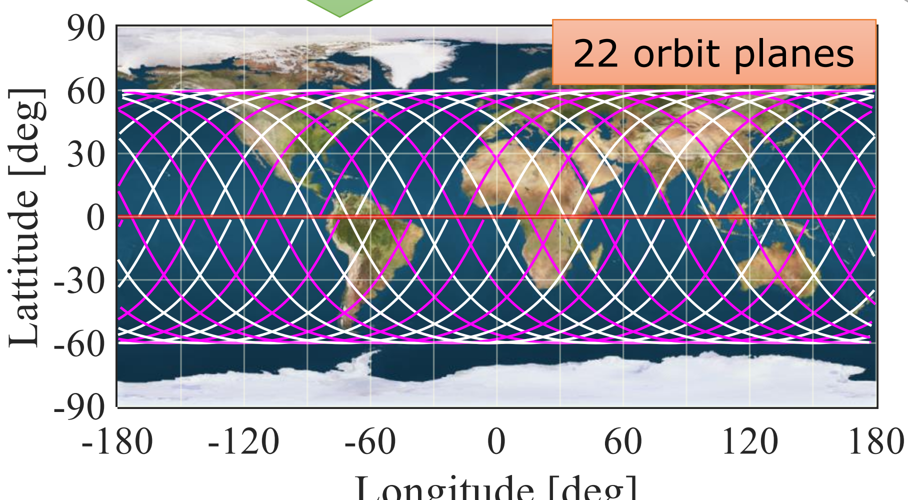
Phase control: Fading



22 times

6 months

Latitudinally alignment
36-degree difference

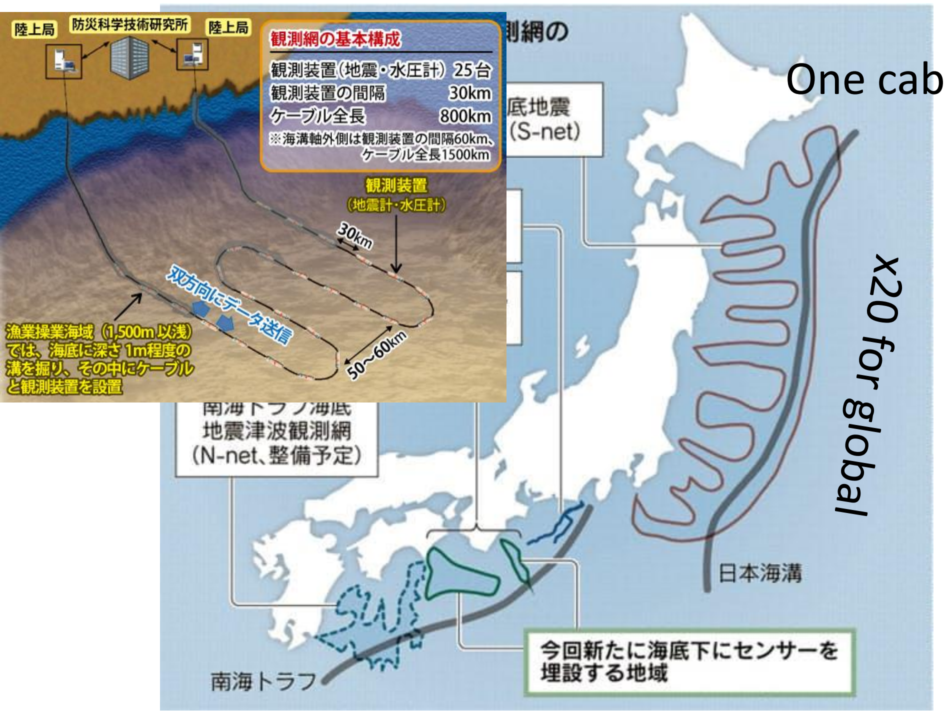


The total 220 satellites construct spatiotemporally uniform observation points in space.

. Implementation plan

Neptune

Mission life period	Practically 2 years
Satellite cost	$0.4 million / 1 sat.
Satellite number for constellation	220
Total satellite cost	$88 million
One rocket cost	$20 million
Total rockets	22
Total rocket cost	$440 million
Total cost	$528 million (per 2 years)



One cable: $2 billion per 30 years.

Ocean bottom cable: $40 billion per 30 years.
(Cable will become waste 30 years later.)

Satellite cable: $9 billion per 30 years.